

THE WORLD OF CHEMISTRY

Program #17

THE PRECIOUS ENVELOPE

Producer John Boslough

Air Script: October 31, 1988

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Annenberg/CPB Project Logo and Music

Funder Credits

MONTAGE: Earth from space,
clouds, smokestacks, weather
balloon, mountain range

NARRATOR (MUSIC under):
The atmosphere is essential to all life on
earth. What is the atmosphere made of,
and how was it formed in the first place?
How has our planet's vital supply of air
changed in the past, and how is it being
threatened by human activities today?
Today's scientists are unlocking these
and other mysteries as they probe our
atmosphere, the precious envelope.

SUPER: THE PRECIOUS
ENVELOPE

THE WORLD OF CHEMISTRY OPEN: Montage, Music, Logo

RH next to water

ROALD HOFFMANN (SYNC):
What does it take to sustain a human being capable of driving a truck, or composing a string quartet, or making a new chemical? Well, let's pare it down to essentials. In one day what it takes is about 2 kilograms of fresh water, about a kilogram of nutritious food, and 16 kilograms of air inhaled. We usually don't think we breathe that much air, but we do. About one-fifth of it is oxygen that we use, the rest nitrogen we mostly exhale. That material's balance is instructive in a number of ways, but what I find in it that is strongest, that comes across most directly, is that it tells me something about the incredible dependence that we have on the air, on the oceans, on the earth under my feet. We live, are sustained on the surface of a planet that is surrounded by a precious and subtle twin atmosphere of air and water that in a thin layer, only 10 kilometers out of the 8,000 from the center of the earth, supports incredible life.

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(Air Script)

MONTAGE: Earth from
space, sunset, clouds,
oceans, storms, flower
blooming, airplane,
crowd at ballgame

NARRATOR (MUSIC and NAT
SOUND under):

The earth is unique. Of all the planets in the solar system, it is the only one with an atmosphere capable of supporting life. This thin membrane not only provides all life on earth with a steady supply of essential oxygen, but it plays other important roles, too. In synchronization with the ocean, the atmosphere brings us the climate and weather that are responsible for our planet's cycles of life. And often to our dismay, dramatic changes in atmospheric conditions bring weather not to our liking. Without a canopy of air, there would be no seasons, airplanes could not fly, and fans could not cheer at a ball game.

GRAPHIC: Diagram of
proportions of different
gases in the atmosphere

NARRATOR (MUSIC under):

The earth's atmosphere consists of various gases. The major ones are displayed here in their relative proportions. Nitrogen, which is essentially inert, makes up 78.1 percent of the atmosphere. Oxygen accounts for 20 percent. (cont.)

NARRATOR cont:

Other gases are argon, a little under 1 percent, and much smaller amounts of carbon dioxide, neon, helium, krypton, xenon, and hydrogen. Still more gases, not shown here, are present in varying concentrations, such as high-altitude ozone. These all form the gaseous mixture we call the atmosphere.

MONTAGE: Earth from space,
Jupiter, steam, smokestacks,
mountain range, wheat and
wheat fields with farm
machinery

NARRATOR (MUSIC and NAT
SOUND under):

Without this vital membrane of air, our planet would be as lifeless as the moons of Jupiter. So it is ironic that, since the advent of the industrial age, humans have been pouring unprecedented amounts of pollutants into the sky. The thin and protective membrane of high-altitude ozone is especially at risk. This delicate ozone layer lies 15 to 40 kilometers above the earth's surface. Molecules of ozone, made of 3 oxygen atoms, block a large portion of the sun's potentially harmful ultraviolet radiation. So the ozone protects life on the planet. Dr. Robert Watson is Chief of Atmospheric Sciences for the National Aeronautics and Space Administration.

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(Air Script)

INTERVIEW: Dr. Robert
Watson, Chief of Atmospheric
Sciences, National Aeronautics
and Space Administration

SUPER: Robert Watson

DR. ROBERT WATSON (SYNC):
The main importance of the ozone layer
is it screens the harmful ultraviolet
radiation from the sun from penetrating
to the surface of the earth. If there was
less ozone in the earth's atmosphere, it
would mean more ultraviolet radiation
would reach the earth's surface with
potential adverse consequences for both
human health, such as skin cancer, both
melanoma and non-melanoma, and
probably would have adverse effects on
the productivity of both aquatic life and
terrestrial life.

MONTAGE: Clouds, air
conditioner, refrigerator,
train cars, factory shots

NARRATOR (NAT SOUND under):
But the ozone layer is threatened by
synthetic substances called
chlorofluorocarbons, or CFCs, that rise
into the upper atmosphere. CFCs are
used mostly as coolants in air
conditioners and in refrigerators, not
only in the home, but in large
refrigeration systems used to transport
perishable food worldwide. (cont.)

NARRATOR cont:
CFCs also are used as solvents to clean computer components and for manufacturing styrofoam. Robert Srubar is environmental coordinator of the Freon Products Division of the Du Pont Company, the world's largest producer of CFCs.

INTERVIEW: Robert Srubar,
Environmental Coordinator,
Freon Products Division,
DuPont Company

SUPER: Robert Srubar

ROBERT SRUBAR (SYNC):
CFCs were first developed in the late 1920s, early 1930s, as replacements for the more toxic or flammable refrigerants. The idea was to have a safer refrigerant for use in your refrigerator at home or in similar machines that are used around the general public. The market value of CFCs in the U.S. is on the order of one billion dollars. Worldwide, it's about three times that much. Products or services related to CFCs in the U.S. are about \$27 billion.

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(Air Script)

MONTAGE: Earth from space,
shots of the South Pole, computer
image of the "black hole" at the
South Pole, research airplanes

NARRATOR (MUSIC and NAT
SOUND under):

During the 1970s, a peculiar depletion
of ozone was detected over the South
Pole. It was the first clue that something
was wrong. By 1985, the Antarctic
ozone hole had doubled in size. This
image of the globe was taken from a
satellite directly above the South Pole.
It shows the black ozone hole changing
in size. In 1987, Dr. Watson and other
scientists used high-altitude research
craft, such as this ER-2 plane operated
by NASA, to take air samples above
Antarctica. These flights confirmed what
they already feared, that the size of the
ozone hole was increasing at an alarming
rate, although it still seemed to be
confined to the atmosphere over
Antarctica.

INTERVIEW: Dr. Robert
Watson cont.

DR. ROBERT WATSON (SYNC):
I was the mission scientist on the DC-8
which actually flew over the South Pole.
It was the urgency of the situation that
convinced all of us that we had to go
down there and devote many months of
our lives just to understand what this
particular campaign was all about, and
specifically what was causing the ozone
hole. (cont.)

(Air Script)

DR. ROBERT WATSON cont:
I've been concerned for many years that even small changes in ozone could be detrimental to human health and to the aquatic and terrestrial plant life on earth. But when we suddenly see a 50 percent change in ozone in only a 10-year period from 1974 through to the middle of the 1980s, a 50 percent, one has to be concerned. One has to ask the simple question, what is causing the Antarctic ozone hole, and even more importantly, will it spread globally.

GRAPHIC: Ozone and CFCs
at the molecular level

NARRATOR (MUSIC under):
Here is a model that describes how ozone might be destroyed in the upper atmosphere. A chlorofluorocarbon is released into the atmosphere from the earth's surface. As the CFC molecules rise into the upper atmosphere, they are bombarded by ultraviolet light, breaking loose a single chlorine atom. The single chlorine atom, in turn, reacts with an ozone molecule, breaking it apart. This creates a molecule of ordinary O₂ and a molecule of chlorine monoxide. Free oxygen atoms exist in the atmosphere, created by the action of light on ordinary O₂ and ozone. This molecule of chlorine monoxide is broken up when it reacts with a free oxygen atom.
(cont.)

(Air Script)

NARRATOR cont:

This creates O₂ and a free chlorine atom. The chlorine atom is then free to attack ozone molecules again. This is a chemical chain reaction. For every chlorine atom released into the atmosphere, thousands of molecules of ozone are removed.

Research airplane,
earth from space

NARRATOR (NAT SOUND under):
Evidence shows that the depletion of ozone is spreading worldwide. A 1988 NASA report indicated that there has been a measurable reduction in ozone levels in the Northern Hemisphere.

INTERVIEW: Robert
Srubar cont.

ROBERT SRUBAR (SYNC):
That information prompted Du Pont to be consistent with its environmental policy and to come forth with our new position, where we set as our goal the orderly transition to a phaseout of the fully halogenated CFC production.

Chemists working in labs

NARRATOR (NAT SOUND under):
Although the full story about ozone depletion is not yet in, chemical manufacturers, like Du Pont, are developing alternatives to CFCs that will not damage the atmosphere.

INTERVIEW: Robert
Srubar cont.

ROBERT SRUBAR (SYNC):
The alternatives that Du Pont is developing or that Du Pont has announced are all in the fluorocarbon family, meaning they contain carbon, fluorine, some contain chlorine. They also would contain hydrogen. And it's those combinations of elements that give the compound its stability, while at the same time, if it has chlorine, it means a much shorter atmospheric lifetime so as not to affect stratospheric ozone. The addition of a hydrogen atom will cut that atmospheric lifetime drastically.

RH at a chemical plant

ROALD HOFFMANN (SYNC):
This is Du Pont's Chambers Works, where many chlorofluorocarbons are now being made, soon to be replaced by, we don't know what yet. Let's come back to ozone, that wonderful gas which, in the upper atmosphere, protects us from ultraviolet radiation. Here down at sea level, that same molecule is a very nasty actor indeed. It's a blue gas with a characteristic strong odor. It's generated around electrical discharges. And we can smell it in concentrations as small as one part in a hundred million. It ruins tires, damages plant life, and is a component of photochemical smog. And, in another context, it's sometimes used to purify water. (cont.)

ROALD HOFFMANN cont:
The moral of the story? There are no clear heroes or villains in the molecular world. There are only molecules in equilibrium with other molecules. The heroes and villains can only be human. The heroes, for instance, are those people who have puzzled out, with ingenuity and with sweat, the mechanisms of ozone depletion, or who, acting by themselves or in concert with others in society, are willing to modify their ways to preserve this atmosphere.

MONTAGE: Ocean, clouds, volcanos, lava flows, earth's horizon, hot springs, forest, smokestacks

NARRATOR (MUSIC and NAT SOUND under):
How do scientists learn more about the threats to the atmosphere? One way is to study how this precious envelope of air evolved over billions of years. Scientists believe that, when the earth was in its infancy, there were many volcanos, far more than today. Energy produced by radioactive decay deep beneath the surface melted rock and forced lava and gases upwards to the surface. These gases formed a primitive atmosphere consisting mostly of methane, ammonia, carbon dioxide, nitrogen, and chlorine. (cont.)

NARRATOR cont:

Denser gases were held near the earth's surface by gravity. Lighter gases, like hydrogen, escaped into space. There also were vast quantities of water vapor which, because of strong intermolecular forces, eventually condensed to form the oceans. How did the primitive atmosphere and the early oceans evolve together to produce life on earth? Probing for that answer may help us understand how these systems stay in balance, and how human activities threaten nature's exquisite balance. One of the best-known researchers in the field is Dr. Cyril Ponnampерuma.

INTERVIEW: Dr. Cyril
Ponnampерuma, University
of Maryland

SUPER: Cyril Ponnampерuma

DR. CYRIL PONNAMPERUMA
(SYNC):

What we have here is an apparatus that gives us an idea of what could have happened on the primitive Earth four and a half billion years ago.

Dr. Ponnampereuma's model

NARRATOR (NAT SOUND under):
The upper flask represents the primitive atmosphere, while the lower one represents the ocean. The early atmosphere was made up mainly of methane, ammonia, and water vapor. This side arm is kept warm, while this condenser is kept cold. Water vapor rises through the warm side arm to the upper flask, much like water evaporating from the ocean, and it falls back through the condenser as if it were rain. This electrical discharge simulates lightning through the primitive atmosphere. When the lightning discharges, a number of reactions take place that could result in the formation of organic matter, which collects in the ocean below.

INTERVIEW: Dr. Cyril
Ponnampereuma cont.

DR. CYRIL PONNAMPERUMA
(SYNC):
Students of chemical evolution who study the origin of life call that the primordial soup. It is believed that the early oceans had an accumulation of organic molecules, the very building blocks of life, amino acids, the bases that occur in the nucleic acid. (cont.)

DR. CYRIL PONNAMPERUMA cont:
In this laboratory, in this very
experiment, we have synthesized all five
of the genetic bases. Now here we have
a wonderful way of simulating the
atmospheric conditions of the early
earth.

MONTAGE: Lightning, storms,
ocean, cells under microscope,
misty forest, swamp, space
shots, measuring tree rings,
sampling ice, tundra, iceberg,
research ship, weather balloon,
wheat field, flood

NARRATOR (MUSIC and NAT
SOUND under):
With the building blocks of amino acids
in place, primitive life could begin to
develop, first as single-celled organisms
originating in the primordial soup of the
sea, later as more complex and adaptable
organisms capable of leaving the water
and living on land. Gradually, some
organisms developed the ability to
release oxygen into the atmosphere.
And from then on, life could begin to
evolve in more complex forms, which,
in turn, helped produce more oxygen
for the atmosphere. To predict how the
atmosphere might change in the future,
scientists today try to discover how it
has changed in the recent past. (cont.)

NARRATOR cont:

One way to measure these changes is by taking samples of tree rings that reflect climatic changes over centuries or even thousands of years. Atmospheric scientists also can track past changes by taking samples of buried ice that formed on the surface long ago. By testing such samples, scientists have shown that the earth was a little warmer about a thousand years ago, and from the 16th to the middle of the 19th centuries, it was about one degree Celsius colder than it is today. For an even deeper look into the past, scientists sample layers of sediments that have settled on the floor of the ocean. Scientists also monitor subtle, but significant, changes occurring in the atmosphere today, since these changes have the potential to enhance life or seriously disrupt global cycles.

GRAPHIC: The hydrologic cycle

NARRATOR (MUSIC under):

One of these cycles is called the hydrologic cycle, the constant movement of water, evaporating from earth to sky as water vapor, and from sky to earth as precipitation. The hydrologic cycle has existed for millenia. It's even possible that, when you take a drink of water, you may be swallowing a molecule or two once drunk by Julius Caesar.
(cont.)

NARRATOR cont:

Powered by the heat of the sun, this slow but steady cycle of evaporation and precipitation is always in balance for the earth as a whole. About 10 percent of all precipitation falls on land and provides us with the supply of fresh water that we depend on.

DS working in lab

NARRATOR (NAT SOUND under):

In the laboratory, series demonstrator Donald Showalter shows how carbon dioxide plays an important role in another cycle vital to life on earth.

DS in lab

DON SHOWALTER (SYNC):

This is bromothymol blue, a nice pretty blue color. Remember the blue. Now, this acid base indicator will change color if there is a change in the acidity of the solution. Let's add some of our carbon dioxide, the dry ice, and see what happens. Notice the dry ice bubbles -- oh, look at that. There's a color change to this beautiful yellow color. Now, what does that mean? Remember, we said this was an acid base indicator. So the carbon dioxide not only dissolved in the solution, but it also changed the acidity of the solution.

Misty forest

NARRATOR:

Photosynthesis by plants also depends on carbon dioxide. An experiment with bromothymol blue demonstrates this vital role.

DS in lab

DON SHOWALTER (SYNC):

Now I have three test tubes here that are filled with water, and then I saturated them with carbon dioxide, just dropped it in there and let it bubble away. I also put some indicator, remember that same indicator, bromothymol blue, so it turned yellow. And then I put a water plant in two of these. Now, this is actually the experiment here. We want to see if the plant will absorb that carbon dioxide, and then the acid content will decrease and we will see a color change, if it happens. What I am gonna do now, I'm gonna take this tube with the plant, and this one over here without, and expose it to an intense light source. I'm going to take this tube out in front here with the plant in it and put it into a dark area where it's not exposed to light. Now, what do you think's gonna happen? Well, there's going to be some change now, we hope, because of the absorption of the carbon dioxide. But that's gonna take quite a bit of time, certainly more than a day. (cont.)

DON SHOWALTER cont:

So I can't sit here and let you watch it while it happens. I've already done that part. Now let me show you what happened. After at least 24 hours now, look what's happened. The solution has turned blue. Now, that means that this water is now less acidic, right? The blue color means less acidic. What happened to the other two, though? Now, remember, this one was in the dark, didn't have any light exposed, and it didn't turn color. And this one now has no plant in it. It was exposed to the light. But it didn't turn color either. Okay. Now, what does this all mean? It means now, for the plant to absorb the carbon dioxide, we need to have the plant, we need to have water, and we need to have light. And if all those are present, the carbon dioxide will be absorbed and the solution will be less acidic.

Lab demo, waves

NARRATOR (MUSIC under):

Carbon dioxide's ability to dissolve in water and its reaction with plants are part of what is called the carbon dioxide cycle. Much of the carbon dioxide gas released throughout geological times by volcanos, and today by respiring animals and plants, is dissolved into the ocean.

GRAPHIC: Carbon dioxide
cycle

NARRATOR (MUSIC under):
In water, carbon dioxide forms a
bicarbonate ion and a carbonate ion.
Some of these end up as calcium
carbonate, an insoluble compound found
mainly in plankton whose skeletal
remains eventually settle to the ocean
floor. Photosynthesis is an important
part of the carbon dioxide cycle. Green
plants use solar energy to convert water
and carbon dioxide into glucose and
oxygen. Oxygen is released into the
atmosphere in enormous quantities. So
as long as there are plants and sunshine
on earth, there will be a never-ending
supply of oxygen in the air.

Water at sunset, smokestacks,
factory shots, automobile
exhaust, airplanes

NARRATOR (MUSIC and NAT
SOUND under):
It has taken eons for the atmosphere to
evolve, but as our experience with ozone
has shown, only a short time for humans
to disrupt this precious envelope. Since
the industrial revolution began over a
century ago, massive amounts of coal
and other fuels have been burned.
Unprecedented amounts of carbon
dioxide have been pumped into the
atmosphere. (cont.)

NARRATOR cont:

Today our species is an agent of nearly geological magnitude. In addition to producing CFCs in vast quantities, another way human activities may be changing the atmosphere is through a mechanism called the greenhouse effect.

INTERVIEW: Dr. Robert
Watson cont.

DR. ROBERT WATSON (SYNC):

We're concerned that, through the greenhouse effect, the earth's system may warm up by only a few degrees, three to five degrees during the next few decades. If there were to be an increase, even of only a few degrees, the concerns we have are simply there might be an increase in sea level, erosion of the coastal areas. There may be change in precipitation patterns. There may be a change in the severity of storms. For example, certain models would predict that the American Midwest may become quite dry, it would go back to the dust bowl of the 1930s, wheat will not grow efficiently there. Whereas the warmer temperatures in Canada and the USSR will mean that there will be far more productivity of grain in the high northern climates. One could envisage out of one's scenario very simply that instead of America being an exporter of wheat, it may become an importer from countries such as Canada and the USSR.

GRAPHIC: The greenhouse effect

NARRATOR (MUSIC under):

Here is how the greenhouse effect works. The atmosphere allows most visible and ultraviolet radiation from the sun to penetrate to the surface. Thermal radiation is emitted from the surface and absorbed by molecules of atmospheric gases such as water vapor and carbon dioxide. These molecules serve as energy banks, releasing energy in the form of heat and making the earth habitable. But this greenhouse effect can become too strong if excessive carbon dioxide accumulates in the air, trapping additional heat and raising the temperature at the surface.

Shots of the sun

NARRATOR (MUSIC under):

As a result, the mean global temperature has risen about one-half degree Celsius during the past century.

SUPER: THE PRECIOUS
ENVELOPE

MONTAGE: Volcanos, oceans,
program graphics, "black hole"
image, chemists at work in labs,
sun over ocean, airplane flying

NARRATOR (MUSIC under):

To review: Current evidence indicates
that our atmosphere developed initially
from gases pouring out of volcanos.

The oceans formed as water vapor
condensed from the early atmosphere.

A series of cycles, such as the
hydrologic and carbon dioxide cycles,
maintain the ongoing relationship
between the atmosphere and the oceans.

Photosynthesis is part of the carbon
dioxide cycle and provides life-giving
oxygen. The possible depletion of the
protective ozone layer is one serious
threat to the atmosphere today.

Chemists are developing substitutes for
the CFCs that seem to be damaging the
ozone. An increase in the greenhouse
effect, caused by an overabundance of
carbon dioxide in the air, is another
danger to our planet. The atmosphere is
absolutely essential to life on earth. This
precious envelope must be protected at
all cost.

RH at weather station

ROALD HOFFMANN (SYNC):

Okay, let it go! We use weather
balloons like this one to probe what goes
on in the atmosphere. (cont.)

ROALD HOFFMANN cont:

And what goes on is not just a function of local weather patterns, but of all those global cycles. These marvelous cycles, on carbon dioxide, on water, they are actually examples of something more general, what we might call budgets, global balances, telling us how the elements and compounds are distributed on the earth, how they are transformed, how they are conserved. You might think of other balances of this type, on phosphorous, on sulfur, on nitrogen, on iron, on other elements essential to the earth. These global cycles reflect the equilibrium that the earth has reached. It's an equilibrium that has evolved with time. And then we came. When we were few, it didn't matter, but now we are a multitude, and our tools enhance the effects of what we do.

Credits, Closing Montage, Closing Music

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